11-17-00 EF409652380US A

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

jc868 U.S. PTO 11/16/00

jc862 U.S. PTO 09/714724 11/16/00

Docket No. **AUS9-2000-0483-US1**

11/16/00

Assistant Commissioner for Patents
Washington, D.C. 20231

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For: **METHOD AND SYSTEM FOR AUTOMATIC LOAD BALANCING OF ADVERTISED SERVICES BY SERVICE INFORMATION PROPAGATION BASED ON USER ON-DEMAND REQUESTS**

Enclosed are also:

X	28	Pages of Specification including an Abstract
X	14	Pages of Claims
X	16	Sheet(s) of Drawings Formals
X		A Declaration and Power of Attorney
X		Form PTO 1595 and assignment of the invention to IBM Corporation
X		Form PTO 1449 and Information Disclosure Statement
X		Copies of References
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CLAIMS AS FILED

FOR	Number Filed		Number Extra		Rate		Basic Fee ($710)
Total Claims	36	-20 =	16	X	$ 18	=	$288
Independent Claims	6	-3 =	3	X	$ 80	=	$240
Multiple Dependent Claims	0			X	$260	=	$0
					Total Filing Fee	=	$1238

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AUS9-2000-0483-US1

METHOD AND SYSTEM FOR AUTOMATIC LOAD BALANCING OF ADVERTISED SERVICES BY SERVICE INFORMATION PROPAGATION BASED ON USER ON-DEMAND REQUESTS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an improved data processing system and, in particular, to a method and apparatus for enhancing network services. Still more particularly, the present invention provides a method and system for configuration and allocation of networked resources.

2. Description of Related Art

In a highly distributed computational system, the applications that perform operations for a given network service may be dispersed on physical devices throughout the network. Applications on other physical devices that desire access to the given network service must be provided with information on the manner in which a connection with the network service can be obtained.

A complete inventory of available networked resources may be distributed throughout the system. In a system in which networked resources are continually going online and offline, a significant amount of attention must be given to dispersing information about the availability of networked resources and their location, both physical location and logical location or organization.

In any given network, the demand for networked resources fluctuates over time. In a highly distributed computing system, all of the computer platforms may have varying needs for networked resources, thereby creating a very dynamic environment for managing networked resources.

Generally, network management software within the distributed computing system satisfies the demand for networked resources using some type of load balancing such that all service requesters eventually get access to the requested service. It is sometimes critical to load balance the demand for services by distributing the request workload across the entire system in order to ensure fair access.

When multiple concurrent access is needed to satisfy the request workload, most existing systems only rely on some internal metrics without any knowledge of the outside environment. For example, a system may monitor its number of concurrent client connections to ensure that the number does not exceed a maximum threshold. Many current load balancing implementations are based on complex algorithms that apply only to a specific configuration.

In order for a load balancing mechanism to operate successfully using internal metrics, a mathematical model of the expected behavior of the system must closely approximate the actual demands that are placed on the system. In a system in which the behavior of its devices and applications can be relatively easily monitored, an accurate model might be easily devised. However, in a highly distributed environment, the load demand can vary

greatly, and it is difficult to devise a load balancing mechanism based on internally derived metrics.

Therefore, it would be advantageous to provide a method and system for automatically load balancing the demand on networked resources based on user-driven demand.

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SUMMARY OF THE INVENTION

A method, a system, an apparatus, and a computer program product for balancing demand for networked services in a distributed data processing system is presented. Each client is uniquely associated with a local service manager; one or more local service managers are located throughout the distributed data processing system, and each local service manager provides access to networked services for associated clients. Each local service manager is uniquely associated with a distributed service manager; one or more distributed service managers are located throughout the distributed data processing system, and each distributed service manager provides access to networked services for associated local service managers. A client sends a request for a networked service to its local service manager. The local service manager returns information about a matching service to the client after finding a matching service that has characteristics that match parameters in the request. If the local service manager does not have information about a matching service, then the request is forwarded to its associated distributed service manager. If the distributed service manager does not have information about a matching service, then the request is broadcast to all distributed service managers. If the distributed service manager has two or more matching services, then it performs a load balancing operation to select a best service to be returned.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, further objectives, and advantages thereof, will be best understood by reference to the following detailed description when read in conjunction with the accompanying drawings, wherein:

Figure 1 illustrates a simplified diagram showing a large distributed computing enterprise environment in which the present invention may be implemented;

Figure 2 is a block diagram depicting a system management framework illustrating a software environment in which the present invention may be implemented;

Figure 3 is a block diagram depicting a configuration of software components that may used to implement the System Service Manager in a preferred embodiment of the present invention;

Figures 4A-4D are a series of flowcharts depicting a manner in which a client program can access a service within the System Service Management framework;

Figure 5 is a block diagram depicting a snapshot of a set of services within a distributed computer environment that is implementing a System Service Manager framework;

Figure 6 is a block diagram showing the manner in which a set of LSMs and DSMs build their relationships within a distributed system implementing a System Services Manager framework;

Figure 7 is a block diagram depicting the manner in which a getService() method may be invoked on a Local Service Manager;

Figure 8 is a block diagram depicting the manner in which a getServices() method may be invoked on a Local Service Manager to obtain advertised services;

Figure 9 is a block diagram depicting some of the actions that are performed when a client tries to access a service remotely;

Figures 10A-10B are block diagrams depicting some of the actions that are generally performed to create, maintain, and provide access to services within the System Service Manager framework;

Figures 11A and 11B show the processing that is performed if a DSM terminates; and

Figure 12 is a block diagram depicting a process for propagating information about services amongst DSMs.

DETAILED DESCRIPTION OF THE INVENTION

With reference now to **Figure 1**, the invention is preferably implemented in a large distributed computer environment **110** comprising many thousands of nodes. The nodes will typically be geographically dispersed, and the overall environment is "managed" in a distributed manner. Preferably, the managed environment is logically organized into a series of loosely-connected managed regions **112**, each of which has its own server **114** for managing local resources within the managed region. Multiple servers **114** coordinate activities across the enterprise and permit remote site management and operation. Each server **114** serves a number of gateway machines **116**, each of which in turn support a plurality of endpoints or terminal nodes **118**. Server **114** may coordinate all activity within the managed region using a terminal node manager (not shown).

Various types of networks may be used to provide communications links between various devices and computers connected together within the distributed data processing system, such as an intranet, a local area network (LAN), or a wide area network (WAN). The network may include permanent connections, such as wire or fiber optic cables, or temporary connections made through telephone or wireless communications. The distributed data processing system may include additional servers, clients, routers and other devices not shown. In the depicted example, the distributed data processing system may include the

Internet within the network representing a worldwide collection of networks and gateways.

The distributed computer environment is managed as a form of client-server architecture with a system management framework. The system management framework includes both client components and server components. The client component is preferably a low cost, low maintenance application suite that is preferably "dataless" in the sense that system management data is not cached or stored by the client component in a persistent manner. Preferably, the system management framework uses an object-oriented approach that facilitates execution of system management services required to manage the resources in the managed region. Such services can be varied and may include, without limitation, file and data distribution, network usage monitoring, user management, and printer or other resource configuration management. Each service is represented in an appropriate manner by one or more objects throughout the distributed environment.

In a large enterprise such as that illustrated in **Figure 1**, there may be one server per managed region with some number of gateways. For a smaller, workgroup-size installation configured on a single LAN, for example, a single server-class machine may be used as both the server and the gateway, and the client machines may run the low cost framework. For larger installations, the managed region may grow breadth-wise with additional gateways being used to balance the load of the endpoints or terminal nodes.

While a server, a gateway, and an endpoint may be software components that may be treated as logically separate entities residing on the same machine, each server, each gateway, and each endpoint are preferably separate machines or computers. For example, each computer may be a RISC-based workstation running the AIX (Advanced Interactive Executive) operation system. It may be assumed that a server is able to support hundreds of simultaneous network connections to remote machines. Each endpoint may also be a separate computer, such as an Intel Pentium-based computer running the Microsoft Windows operating system. Servers, gateways, and endpoints may also be represented by a variety of computing devices, such as mainframes, personal computers, personal digital assistants (PDAs), etc.

Figure 1 is intended as an example of a heterogeneous computing environment and not as an architectural limitation for the present invention. The present invention could be implemented on a variety of networks. Those of ordinary skill in the art will also appreciate that the hardware in **Figure 1** may vary depending on the system implementation. The depicted examples are not meant to imply architectural limitations with respect to the present invention. In addition to being able to be implemented on a variety of hardware platforms, the present invention may be implemented in a variety of software environments.

It is important to note that while the present invention is described in the context of a fully functioning data processing system, those of ordinary skill in the art will appreciate that the processes of

the present invention are capable of being distributed in the form of instructions in a computer readable medium and a variety of other forms, regardless of the particular type of signal bearing media actually used to carry out the distribution. Examples of computer readable media include media such as EPROM, ROM, tape, paper, floppy disc, hard disk drive, RAM, and CD-ROMs and transmission-type media, such as digital and analog communications links.

With reference now to **Figure 2**, a block diagram depicts a system management component illustrating a software environment in which the present invention may be implemented. Each machine **210** within the system runs component **212** of the system management framework. Component **212** may be a multi-threaded runtime process that comprises several sub-components: object request broker (ORB) **221**; security service **223**; and directory service **225**. Component **212** also includes object library **229** and service manager **231**. Preferably, ORB **221** runs continuously, separate from the operating system. The ORB may be an instance of a CORBA ORB; CORBA is a specification for an object-oriented distributed computer systems management architecture provided by the Object Management Group (OMG), a non-profit association of companies. Computer **210** also includes operating system **235** and may contain some form of interprocess communication facility for supporting communication between server and client objects and processes.

The present invention may be implemented on a variety of hardware and software platforms, as described

above. More specifically, though, the present invention is directed to automatically load balancing the demand for networked resources based on user-driven demand. A System Service Manager (SSM) provides access to services for client-server entities or peer-to-peer entities on a network. Its main function is to manage the services to enable clients to access services in a uniform manner. The SSM preferably provides: decentralized operation such that the SSM requires little administrative intervention in small installations and limited administrative intervention in large enterprise deployments; scalability from few to many servers; optional administrative grouping of services so that administrators can configure the SSM so that clients can only discover an intended set of services through a site policy; and robust access to services that allows access by certain characteristics, e.g., allowing a client to find an appropriate backup service if another service fails.

The SSM supports services that must be started locally in order to have the ORB provide full functionality, and the SSM also supports optional services that publish information outside of the scope of the ORB that may be used by clients, such as user applications, other services, etc.

Services may be placed into three categories: local ORB services, which are services that provide internal services and are only valid in the local ORB scope; non-advertised services, which are instantiated on each ORB and, therefore, do not need to be advertised; and advertised services, which may be accessed from outside of the scope of the local ORB.

With reference now to **Figure 3**, a block diagram depicts a configuration of software components that may used to implement the System Service Manager in a preferred embodiment of the present invention. The System Service Manager (SSM) framework is logically built around two different types of components, the Local Service Manager (LSM) and the Distributed Service Manager (DSM). The SSM uses the Configuration Service to enable customization of various LSMs and DSMs. The Configuration Service can also be used to retrieve a specific service configuration.

An LSM is a piece of code running on each node of a distributed computing environment. An LSM has the same lifecycle as the ORB, and an LSM's main responsibility is to keep track of the services defined locally and to provide access to all of the services within the System Service Manager infrastructure. DSMs are located throughout the distributed computing environment and act as gateways for LSMs in order to access service configuration information and LSM location information. The DSMs also provide load balancing by minimizing the paths and the requests to access the services, as is described in more detail further below. The Configuration Service is a service that provides static information about the services, which are registered into the Configuration Service at installation time.

ORB **310** supports System Service Manager functionality **320**, which is a group of SSM components. The SSM components are shown within ORB **310** to indicate their reliance on the ORB to support their own functionality; however, the SSM components should not be

considered as integral to the ORB but rather as co-located with the ORB, more like components within service manager **231** shown in **Figure 2**. In this example, ORB **310** concurrently supports LSM instance **322**, DSM instance **324**, and Configuration Service component instance **326**. It should be noted, however, that a given ORB supports at least one LSM and may support a DSM.

The DSMs are designed to perform several tasks. The DSMs act as relays in the process of forwarding a request to get access to an SSM service. DSMs cache the proxies to the services in order to maintain a constant level of performance across a network, and DSMs can also locate other DSMs within the same region.

DSMs also achieve a portion of the load balancing functionality by being distributed throughout the distributed computing environment in strategic locations. Each DSM contains localization module **328** that enables the load balancing functionality of a DSM to be customized. Since the DSMs are distributed through the network, each DSM may execute on a unique hardware platform with a unique set of supported services and with a unique demand load for requested services. Each DSM can be customized by establishing parameters within its localization module so that the DSM performs its load balancing duties in a manner that is tailored for the functionality desired from each DSM.

After initialization, every LSM is connected to at least one DSM. The LSMs only manage the lifecycle of services that are defined locally. The LSM gets the service configuration information from the Configuration Service. The Configuration Service entries describe

properties related to the services as appropriate to the type of service. After being started by the ORB, the LSM keeps track of all the services defined by the Configuration Service and waits for client requests to access the SSM services. For example, at some point in time, an application on a node may request a service with particular properties, such as a local print service at a specific building location "BLDG1" and a specific floor location "FLR3". The LSM can determine whether a print service is available by searching for a service entry with those properties. If a matching service is not found, then the LSM can notify the requester that the requested service is not available.

Various types of services may be active within the distributed computing environment at any given time. For example, services are installed and configured through the Configuration Service. Each service is delivered as one or more software components with an accompanying service template file that describes the service. Another service is the Planning and Distribution Service, which can use the service template file as input into the Configuration Service, thereby receiving the information that will later be used by the LSM to manage the service. While many types of services are present in the distributed environment, the present invention is directed to the functionality of distributed load balancing, and other services that are not critical to the operation of the present invention are not presented in detail.

As noted above, services may be categorized as local ORB services, non-advertised services, and advertised

services. An LSM provides access to the SSM services based on the following considerations: an LSM does not provide access to local ORB services; an LSM provides access to non-advertised services only through requests based on an ORB identifier; and an LSM provides access to advertised services through requests based on both a service specification string and an ORB identifier.

With reference now to **Figures 4A-4D**, a series of flowcharts depict a manner in which a client program can access a service within the System Service Management framework. A client receives references to services through a call to either a getService() method or a getServices() method. If the client uses the getService() method, then a best selection for a service that matches the client's request is returned to the client when available. If the client uses the getServices() method, then all services that match the client's request are returned to the client. The flowcharts shown in **Figures 4A-4D** describe the use of the getService() method. The use of the getServices() method is described further below.

Referring to **Figure 4A**, the process starts when a client issues a call to the directory service to locate an access manager (step **410**), and the client then receives a reference to the access manager (step **412**). The access manager provides a single entry point or interface for accessing both services and component objects.

The client then issues a call to the access manager through the getService() method implemented by the LSM (step **414**). The process then completes when the client

receives a reference for a matching service from the LSM (step **416**). However, if no matching service were available, then the client would receive some type of status from the LSM indicating that a service that matches the request is not available.

Referring to **Figure 4B**, a flowchart shows the manner in which an LSM processes a request from a client. The process begins when the getService() method of the LSM is invoked by a client (step **420**). The LSM makes a determination whether or not a service known to the LSM has parameters that match the service characteristics in the request (step **422**). If so, then the LSM returns a reference to the matching service to the requesting client (step **424**), and the process is complete.

If the LSM does not have any knowledge of a service that would match the request, as determined in step **422**, then the LSM forwards the request to its DSM (step **426**). At some later time, the LSM receives a reference to a service from the DSM that fulfills the request (step **428**). The LSM then returns the reference from the DSM to the requesting client (step **430**), and the portion of the process on the LSM is complete. However, if the LSM does not receive a references from its DSM, the LSM may inform the requesting client with an appropriate status message. Alternatively, the requesting client may timeout requests to the LSM.

Referring now to **Figure 4C**, a flowchart shows the manner in which a DSM processes a request from one of its LSMs. The process begins when the DSM receives a request from an LSM (step **440**). The DSM checks whether or not it

has any cached proxies for one or more services that have characteristics that match the parameters specified in the request (step **442**). If so, then the process branches for appropriate processing.

If the DSM does not have any knowledge of any matching services, then the DSM publishes or broadcasts a message to all DSMs to search for a service that matches the request (step **444**). At some later time, the DSM determines whether or not the DSM has received one or more references from other DSMs for services that match the request (step **446**). If not, then the DSM may optionally return a status message to the LSM to inform the LSM that no matching services have been found (step **448**), and the portion of the process within the DSM is then complete.

If the DSM has received at least one reference for a matching service from another DSM, then the DSM caches the reference or references (step **450**). The DSM then makes a determination whether or not the DSM has knowledge of multiple services that fulfill the original request (step **452**).

If the DSM has knowledge of multiple services that can fulfill the request, then the DSM performs an internal load balancing process to obtain the best selection of a single service (step **454**). At this point, the DSM may invoke its localization module, which provides parameters to be used during the load balancing process. When more than one matching service is known at the DSM level, the localization module can compare characteristics of the matching services with specified parameters in the localization module.

For example, the localization module may inform a load balancing routine to examine the hop count (HC), the bottleneck link speed (BLS), or return trip time (RTT) for a matching service. A hop count is determined from the number of discreet transmissions, or hops, between the requester or DSM and the device on which the matching service resides, i.e. the number of times which a packet must be routed along a network path. The bottleneck link speed is determined from the slowest transmission speed of any link within the network path between the requester or DSM and the device on which the matching service resides. The return trip time is the amount of time to receive a response from a service at a requester or DSM, which may depend on both the HC or BLS.

The localization module may examine the HC, BLS, or RTT, or some combination of these or other network-related parameters or metrics, in order to determine which matching service seems to be the best selection for the given requesting client. It should be noted that the HC, the BLS, or the RTT may be determined at network configuration time or in real-time by gathering this information at the DSM when performing a load balancing operation.

After selecting either the best matching service, as determined in step **454**, or the only matching service, as determined in step **452**, the DSM returns a reference for a matching service to the LSM (step **456**), and the portion of the requesting process within the DSM is complete.

Referring now to **Figure 4D**, a flowchart shows the manner in which a DSM processes a broadcast request from another DSM. The process begins when the DSM receives a

broadcast request from another DSM (step **460**). The DSM determines whether it has any cached proxies for one or more matching services already available at the DSM (step **462**). If not, then the broadcast request may be ignored, and the process is then complete.

If the DSM has one or more matching services, then the DSM returns references for all matching services to the broadcasting DSM (step **464**), and the process is complete.

With reference now to **Figure 5**, a block diagram depicts a snapshot of a set of services within a distributed computer environment that is implementing a System Service Manager framework in accordance with a preferred embodiment of the present invention. System **500** merely illustrates an exemplary system and some of the processing within the system; the manner in which services are accessed is shown in more detail further below with respect to **Figures 6-12**.

System **500** contains nodes **510**, **520**, **530**, **540**, **550**, and **560**, which contain LSMs **511**, **521**, **531**, **541**, **551**, and **561** respectively. Service **S0** does not need to be advertised because it is running on all of the nodes; therefore, the only way to access service **S0** is through an ORB ID that specifies the target node. Services **S1-S4** are advertised, and DSM **532** is maintaining proxies **P1-P4** for services **S1-S4**, respectively. When client **563** tries to access service **S0** on node **540** by specifying the proper ORB identifier, the request is forwarded directly to target node **540** by LSM **561**. For that request, DSM **532** is not involved, and LSM **561** handles the whole request.

When client **563** tries to access the advertised service **S2** through a service specification string, the request is forwarded to DSM **532**, and DSM **532** returns a cached proxy **P2** to LSM **561**, which is returned to client **563**.

With reference now to **Figure 6**, a block diagram shows the manner in which a set of LSMs and DSMs build their relationships within a distributed system implementing a System Services Manager framework in accordance with a preferred embodiment of the present invention. Every time an ORB is initialized, the ORB also starts an instance of an LSM, to which it passes a DSM reference. The DSM may be local or remote according to the environment configuration. When a DSM and a LSM are co-located on the same node, the LSM receives the reference of the local DSM instead of a reference to a remote DSM.

System **600** contains nodes **610**, **620**, **630**, **640**, and **650**, which contain LSMs **611**, **621**, **631**, **641**, and **651**, respectively. Node **610** contains DSM **612**, and node **640** contains DSM **642**. LSMs **611**, **621**, and **631** receive a reference to DSM **612**, whereas LSMs **641** and **651** receive a reference to DSM **642**.

With reference now to **Figure 7**, a block diagram depicts the manner in which a getService() method may be invoked on a Local Service Manager. System **700** contains nodes **710** and **720**, which contain LSMs **711** and **721**, respectively. LSM **721** manages service **S1** and has proxy **P1** for service **S1**. Node **710** also contains DSM **712**, which has a cached copy of proxy **P1**. Client **723** requests access to service **S1** located on the same machine using

the getService() method. Since service **S1** is a service that has been previously started locally, a match is found by LSM **721**, and proxy **P1** is returned to client **723** without any interaction with DSM **712**.

With reference now to **Figure 8**, a block diagram depicts the manner in which a getServices() method may be invoked on a Local Service Manager to obtain advertised services. When a request is performed using the getServices() method, all of the DSMs are called to check if they maintain a proxy that matches the input criteria. All of the matching proxies are then returned to the caller. A client may use the getServices() method instead of the getService() method if the client desires to perform its own selection from among multiple available services.

System **800** contains nodes **810**, **820**, and **830**, which contain LSMs **811**, **821**, and **831**, respectively. LSM **821** manages service **S1** and has proxy **P1** for service **S1**. Node **830** contains DSM **832**. Node **810** also contains DSM **812**, which has a cached copy of proxy **P1**. LSM **811** also manages an instance of service **S1'**, and DSM **812** has a cached copy of proxy **P1'**.

Client **823** invokes the getServices() method for services with particular criteria, which happens to match service **S1** on node **820**. Since service **S1** is a service that has been previously started locally, a match is found by LSM **821**, and LSM **821** returns proxy **P1** that matches the criteria locally. The request is then forwarded to DSM **812**, which also forwards the request to all of the other DSMs. DSM **812** also maintains a proxy

P1' to a service **S1'** that matches the requested criteria, and proxy **P1'** is also returned to client **823**. Since DSM **832** does not maintain any references to a service **S1** or any services that fulfill the request, DSM **832** does not respond.

With reference now to **Figures 9A-9B**, block diagrams depict some of the actions that are performed when a client tries to access a service remotely. System **900** contains nodes **910** and **920**, which contain LSM **911** and **921**, respectively. Node **910** also contains DSM **912**, which shares proxy **P1** with LSM **911** that is supporting service **S2**.

Referring to **Figure 9A**, client **923** sends a request to access service **S2** to LSM **921**, which checks an internal table to determine if it maintains a proxy to service **S2** that matches the criteria of the request. After LSM **921** determines that it has no matching proxy, LSM **921** checks if DSM **912**, to which it is connected, holds a reference to service **S2**. DSM **912** knows about service **S2**, so it returns proxy **P2** for service **S2** to LSM **921**. Before returning the proxy, DSM **912** may check to determine whether service **S2** is still alive by issuing a request to service **S2** and checking if service **S2** responds to the request.

Referring now to **Figure 9B**, DSM **912** has multiple cached proxies **P2'**, **P2''**, and **P2'''** from which DSM **912** may select a best service after performing an internal load balancing process. Each of the proxies **P2'**, **P2''**, and **P2'''** have been previously cached when DSM **912** attempted to fulfill prior requests and received

references to other services from other DSMs within the network (not shown).

With reference now to **Figures 10A-10B**, block diagrams depict some of the actions that are generally performed to create, maintain, and provide access to services within the System Service Manager framework in accordance with a preferred embodiment of the present invention. In both **Figures 10A-10B**, system **1000** contains nodes **1010**, **1020**, **1030**, **1040**, and **1050**, which contain LSMs **1011**, **1021**, **1031**, **1041**, and **1051**, respectively. LSM **1021** manages service **S1** and has proxy **P1** for service **S1**. Node **1040** contains DSM **1042**, which shares proxy **P2** with LSM **1041** that manages service **S2**. Node **1010** also contains DSM **1012**, which has a cached copy of proxy **P1**. LSMs **1021** and **1031** are connected to DSM **1012**. LSM **1041** and LSM **1051** are connected to DSM **1042**.

Referring to **Figure 10A**, when client **1033** attempts to access service **S2**, a request is sent to LSM **1031**, which does not know about service **S2**, so the request is forwarded to DSM **1012**. Since DSM **1012** does not have any knowledge about service **S2**, it publishes or broadcasts a message looking for a DSM that has knowledge about service **S2**. DSM **1042** knows about service **S2**, so DSM **1042** returns all available information about it. DSM **1012** then caches a copy of proxy **P2** locally and returns proxy **P2** to LSM **1031**, which is returned to client **1033**. If client **1053** desires access to service **S1**, a similar process would be followed, resulting in proxy P1 being stored by DSM **1042**.

Referring to **Figure 10B**, after running for a while, the system will reach equilibrium with proxies to a given service equally distributed among all the DSMs. **Figure 10B** shows proxy **P2** cached at DSM **1012** and proxy **P1** cached at DSM **1042**.

With reference now to **Figures 11A and 11B**, two diagrams show the processing that is performed if a DSM terminates. Each LSM implements a monitoring mechanism that detects if the DSM to which it is connected is up and running. System **1100** contains nodes **1110**, **1120**, **1130**, **1140**, and **1150**, which contain LSMs **1111**, **1121**, **1131**, **1141**, and **1151**, respectively. Node **1140** contains DSM **1142**, and node **1110** also contains DSM **1112**. LSMs **1111**, **1121**, and **1131** are connected to DSM **1112**, and LSM **1141** and LSM **1151** are connected to DSM **1142**.

When LSM **1151** detects that DSM **1142** has failed, LSM **1151** publishes or broadcasts a message to get a reference to a new DSM. Once a new reference is received, LSM **1151** can upload all of the information related to the services that LSM **1151** is managing. In **Figure 11B**, LSM **1151** has received a reference to DSM **1112**.

With reference now to **Figure 12**, a block diagram depicts a process for propagating information about services amongst DSMs. System **1200** contains nodes **1210**, **1220**, **1230**, and **1240**. Node **1210** contains DSM **1212**, and node **1220** contains LSM **1221**. Node **1230** contains DSM **1232**, and node **1240** contains LSM **1241** and DSM **1242**. LSM **1221** manages service **S1**, and LSM **1241** supports client **1243**. LSM **1241** is connected to DSM **1242**, and LSM **1221** is connected to DSM **1212**.

Service **S1** is started through LSM **1221** and advertised by DSM **1212**. When client **1243** wants access to service **S1**, LSM **1241** forwards the request to DSM **1242** because LSM **1241** does not have any knowledge of service **S1**. As DSM **1242** does not have any references for service **S1**, DSM **1242** tries to contact a DSM within the environment that may know about service **S1**. DSM **1242** publishes or broadcasts a REQUEST_FOR_ONE_SERVICE message, putting its ORB identifier into the source field of the message and a null in the destination field. The null means that all DSMs must check whether they can fulfill the request in the message, and all DSMs receive the message. DSM **1232** receives the message but discards it because it does not know about service **S1**. DSM **1242** also receives the message and discards it because the Oid is its own Oid. However, DSM **1212** will receive and process the message because it knows about service **S1**.

DSM **1212** publishes a REPLY_TO_ONE_SERVICE message with the service information for service **S1**. The source Oid is swapped to the destination field, and DSM **1212** puts its Oid in the source field of the message. The message is then published or broadcast, which is then received by every DSM in the environment. DSM **1212** and DSM **1232** discard the message because the Oid in the destination field does not match its Oid. DSM **1242** processes the message because the destination Oid matched its internal Oid. It stores the **S1** service information locally and returns the proxy to LSM **1241**, which then returns it to client **1243**.

Services can also be removed from the environment. If an LSM gets a proxy from a DSM, it may test it and discover that the proxy is invalid. In this case, the LSM calls a deprecateServiceRef() method on the DSM to which it is connected. The DSM then publishes or broadcasts a DEPRECATE_SVC_INFO message to the other DSMs. By setting the destination field to null, every DSM will check the message, and every DSM subsequently checks its internal repository to see if any service information matches the request. If so, then the DSM invalidates its internal entry.

The advantages of the present invention should be apparent in view of the detailed description of the invention that is provided above. The processing required for fulfilling a request for a service is distributed through Local Service Managers (LSMs) and Distributed Service Managers (DSMs). The present invention automatically load balances according the scope of the requests issued by the clients connected to the distributed environment. A networked service's visibility is propagated based on matching criteria and not according to the load of the machine supporting the services.

The description of the present invention has been presented for purposes of illustration but is not intended to be exhaustive or limited to the disclosed embodiments. Many modifications and variations will be apparent to those of ordinary skill in the art. The embodiments were chosen to explain the principles of the invention and its practical applications and to enable others of ordinary skill in the art to understand the

invention in order to implement various embodiments with various modifications as might be suited to other contemplated uses.

CLAIMS

What is claimed is:

1. A method of balancing a workload across a plurality of servers, the method comprising the steps of:

responsive to a request from a requesting client for a distributed service, forwarding the request to a first distributed service manager associated with the requesting client;

determining whether the first distributed service manager has information about the distributed service;

if the first distributed service manager has information about the distributed service, retrieving the information about the distributed service;

if the first distributed service manager does not have information about the distributed service, retrieving information about the distributed service from a second distributed service manager and caching the retrieved information at the first distributed service manager; and

sending the retrieved information to the requesting client.

2. The method of claim 1 wherein the first distributed service manager has information about at least two sources for the distributed service and selects a source which will provide best service to the requesting client based on network performance metrics.

3. A method of balancing demand for networked services in a distributed data processing system, the method comprising the steps of:

initializing one or more local service managers within the distributed data processing system, wherein each local service manager provides access to networked services for clients within the distributed data processing system, and wherein each client is uniquely associated with a local service manager;

initializing one or more distributed service managers within the distributed data processing system, wherein each distributed service manager provides access to networked services to local service managers within the distributed data processing system, and wherein each local service manager is uniquely associated with a distributed service manager;

receiving, at a distributed service manager, a request for a networked service from a local service manager;

determining whether the distributed service manager has information about a networked service with one or more characteristics that match one or more parameters in the request for a networked service; and

returning information about a matched networked service from the distributed service manager to the local service manager.

4. The method of claim 3 further comprising:

sending a request for a networked service from a requesting client to a local service manager associated with the requesting client; and

returning information about a matching networked service from the local service manager to the requesting client, wherein the matching networked service has characteristics that match parameters in the request for a networked service.

5. The method of claim 3 further comprising:

receiving a request for a networked service at a local service manager; and

determining whether the local service manager has information about a networked service with characteristics that match parameters in the request for a networked service.

6. The method of claim 5 further comprising:

if the local service manager has information about a matching networked service, returning the information about the matching networked service to the requesting client;

if the local service manager does not have information about a matching networked service, forwarding the request for a networked service from the local service manager to a distributed service manager associated with the local service manager.

7. The method of claim 3 further comprising:

if the distributed service manager has information about a matching networked service, returning the information about the matching networked service to the local service manager;

if the distributed service manager does not have information about a matching networked service, broadcasting the request for a networked service from the distributed service manager to all distributed service managers in the distributed data processing system;

receiving information about one or more matching networked services at the distributed service manager in response to the broadcast request; and

caching the received information about one or more matching networked services at the distributed service manager.

8. The method of claim 3 further comprising:

in response to a determination that the distributed service manager has information about two or more matching networked services, selecting a single networked service at the distributed service manager.

9. The method of claim 8 further comprising:

performing a load balancing operation at the distributed service manager to select the single networked service.

10. The method of claim 9 further comprising:

comparing network-related metrics during the load balancing operation.

11. The method of claim 10 further comprising:

comparing one or more of network-related metrics associated with a network path between a requesting client and a providing server.

12. The method of claim 11 wherein the network-related metrics are selected from a group comprising: bottleneck-link speed, round-trip time, and hop count.

13. An apparatus for balancing a workload across a plurality of servers, the apparatus comprising:

forwarding means for forwarding, responsive to a request from a requesting client for a distributed service, the request to a first distributed service manager associated with the requesting client;

determining means for determining whether the first distributed service manager has information about the distributed service;

first retrieving means for retrieving, if the first distributed service manager has information about the distributed service, the information about the distributed service;

second retrieving means for retrieving, if the first distributed service manager does not have information about the distributed service, information about the distributed service from a second distributed service manager;

caching means for caching retrieved information at the first distributed service manager; and

sending means for sending the retrieved information to the requesting client.

14. The apparatus of claim 13 further comprising:

selecting means for selecting a source which will provide best service to the requesting client based on network performance metrics when the first distributed service manager has information about at least two sources for the distributed service.

15. An apparatus for balancing demand for networked services in a distributed data processing system, the apparatus comprising:

first initializing means for initializing one or more local service managers within the distributed data processing system, wherein each local service manager provides access to networked services for clients within the distributed data processing system, and wherein each client is uniquely associated with a local service manager;

second initializing means for initializing one or more distributed service managers within the distributed data processing system, wherein each distributed service manager provides access to networked services to local service managers within the distributed data processing system, and wherein each local service manager is uniquely associated with a distributed service manager;

first receiving means for receiving, at a distributed service manager, a request for a networked service from a local service manager;

first determining means for determining whether the distributed service manager has information about a networked service with one or more characteristics that match one or more parameters in the request for a networked service; and

first returning means for returning information about a matched networked service from the distributed service manager to the local service manager.

16. The apparatus of claim 15 further comprising:

sending means for sending a request for a networked service from a requesting client to a local service manager associated with the requesting client; and

second returning means for returning information about a matching networked service from the local service manager to the requesting client, wherein the matching networked service has characteristics that match parameters in the request for a networked service.

17. The apparatus of claim 15 further comprising:

first receiving means for receiving a request for a networked service at a local service manager; and

second determining means for determining whether the local service manager has information about a networked service with characteristics that match parameters in the request for a networked service.

18. The apparatus of claim 17 further comprising:

third returning means for returning, if the local service manager has information about a matching networked service, the information about the matching networked service to the requesting client.

forwarding means for forwarding, if the local service manager does not have information about a matching networked service, the request for a networked service from the local service manager to a distributed service manager associated with the local service manager.

19. The apparatus of claim 15 further comprising:

fourth returning means for returning, if the distributed service manager has information about a matching networked service, the information about the matching networked service to the local service manager;

broadcasting means for broadcasting, if the distributed service manager does not have information about a matching networked service, the request for a networked service from the distributed service manager to all distributed service managers in the distributed data processing system;

second receiving means for receiving information about one or more matching networked services at the distributed service manager in response to the broadcast request; and

caching means for caching the received information about one or more matching networked services at the distributed service manager.

20. The apparatus of claim 15 further comprising:

selecting means for selecting, in response to a determination that the distributed service manager has information about two or more matching networked services, a single networked service at the distributed service manager.

21. The apparatus of claim 20 further comprising:

performing means for performing a load balancing operation at the distributed service manager to select the single networked service.

22. The apparatus of claim 21 further comprising:

first comparing means for comparing network-related metrics during the load balancing operation.

23. The apparatus of claim 22 further comprising:

second comparing means for comparing one or more of network-related metrics associated with a network path between a requesting client and a providing server.

24. The apparatus of claim 23 wherein the network-related metrics are selected from a group comprising: bottleneck-link speed, round-trip time, and hop count.

25. A computer program product on a computer readable medium for use in a data processing system for balancing a workload across a plurality of servers, the computer program product comprising:

forwarding means for forwarding, responsive to a request from a requesting client for a distributed service, the request to a first distributed service manager associated with the requesting client;

determining means for determining whether the first distributed service manager has information about the distributed service;

first retrieving means for retrieving, if the first distributed service manager has information about the distributed service, the information about the distributed service;

second retrieving means for retrieving, if the first distributed service manager does not have information about the distributed service, information about the distributed service from a second distributed service manager;

caching means for caching retrieved information at the first distributed service manager; and

sending means for sending the retrieved information to the requesting client.

26. The computer program product of claim 25 further comprising:

selecting means for selecting a source which will provide best service to the requesting client based on network performance metrics when the first distributed service manager has information about at least two sources for the distributed service.

27. A computer program product on a computer readable medium for use in a data processing system for balancing demand for networked services in a distributed data processing system, the computer program product comprising:

instructions for initializing one or more local service managers within the distributed data processing system, wherein each local service manager provides access to networked services for clients within the distributed data processing system, and wherein each client is uniquely associated with a local service manager;

instructions for initializing one or more distributed service managers within the distributed data processing system, wherein each distributed service manager provides access to networked services to local service managers within the distributed data processing system, and wherein each local service manager is uniquely associated with a distributed service manager;

instructions for receiving, at a distributed service manager, a request for a networked service from a local service manager;

instructions for determining whether the distributed service manager has information about a networked service with one or more characteristics that match one or more parameters in the request for a networked service; and

instructions for returning information about a matched networked service from the distributed service manager to the local service manager.

28. The computer program product of claim 27 further comprising:

instructions for sending a request for a networked service from a requesting client to a local service manager associated with the requesting client; and

instructions for returning information about a matching networked service from the local service manager to the requesting client, wherein the matching networked service has characteristics that match parameters in the request for a networked service.

29. The computer program product of claim 27 further comprising:

instructions for receiving a request for a networked service at a local service manager; and

instructions for determining whether the local service manager has information about a networked service with characteristics that match parameters in the request for a networked service.

30. The computer program product of claim 29 further comprising:

instructions for returning, if the local service manager has information about a matching networked service, the information about the matching networked service to the requesting client;

instructions for forwarding, if the local service manager does not have information about a matching networked service, the request for a networked service

from the local service manager to a distributed service manager associated with the local service manager.

31. The computer program product of claim 27 further comprising:

instructions for returning, if the distributed service manager has information about a matching networked service, the information about the matching networked service to the local service manager;

instructions for broadcasting, if the distributed service manager does not have information about a matching networked service, the request for a networked service from the distributed service manager to all distributed service managers in the distributed data processing system;

instructions for receiving information about one or more matching networked services at the distributed service manager in response to the broadcast request; and

instructions for caching the received information about one or more matching networked services at the distributed service manager.

32. The computer program product of claim 27 further comprising:

instructions for selecting, in response to a determination that the distributed service manager has information about two or more matching networked services, a single networked service at the distributed service manager.

33. The computer program product of claim 32 further comprising:

instructions for performing a load balancing operation at the distributed service manager to select the single networked service.

34. The computer program product of claim 33 further comprising:

instructions for comparing network-related metrics during the load balancing operation.

35. The computer program product of claim 34 further comprising:

instructions for comparing one or more of network-related metrics associated with a network path between a requesting client and a providing server.

36. The computer program product of claim 35 wherein the network-related metrics are selected from a group comprising: bottleneck-link speed, round-trip time, and hop count.

ABSTRACT OF THE DISCLOSURE

METHOD AND SYSTEM FOR AUTOMATIC LOAD BALANCING OF ADVERTISED SERVICES BY SERVICE INFORMATION PROPAGATION BASED ON USER ON-DEMAND REQUESTS

A methodology for balancing demand for networked services in a distributed data processing system is presented. Each client is uniquely associated with a local service manager; one or more local service managers are located throughout a distributed data processing system, and each local service manager provides access to networked services for associated clients. Each local service manager is uniquely associated with a distributed service manager; one or more distributed service managers are located throughout the distributed data processing system, and each distributed service manager provides access to networked services for associated local service managers. A client sends a service request to its local service manager, which returns information about a matching service to the client after finding a matching service that has characteristics that match parameters in the request. If the local service manager does not have information about a matching service, then the request is forwarded to its associated distributed service manager. If the distributed service manager does not have information about a matching service, then the request is broadcast to all distributed service managers. If the distributed service manager has two or more matching services, then it performs a load balancing operation to select a best service to be returned.

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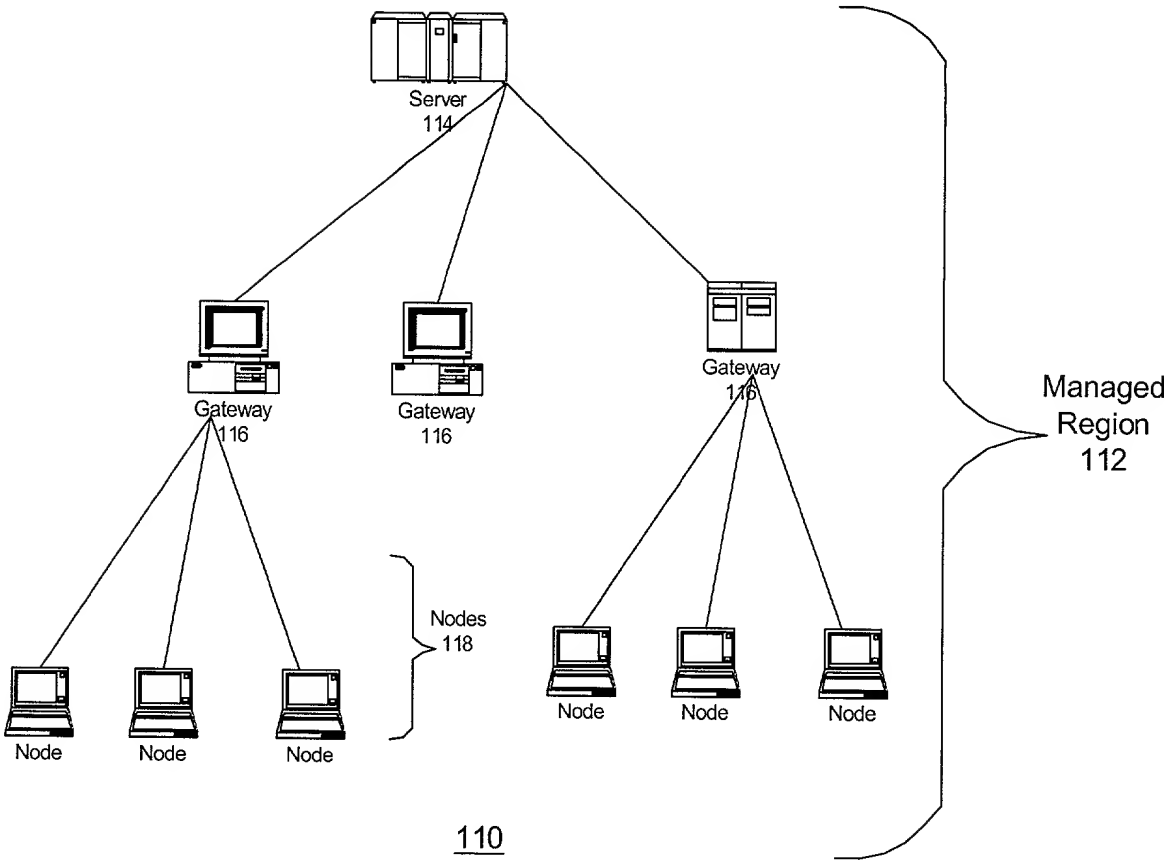


Figure 1

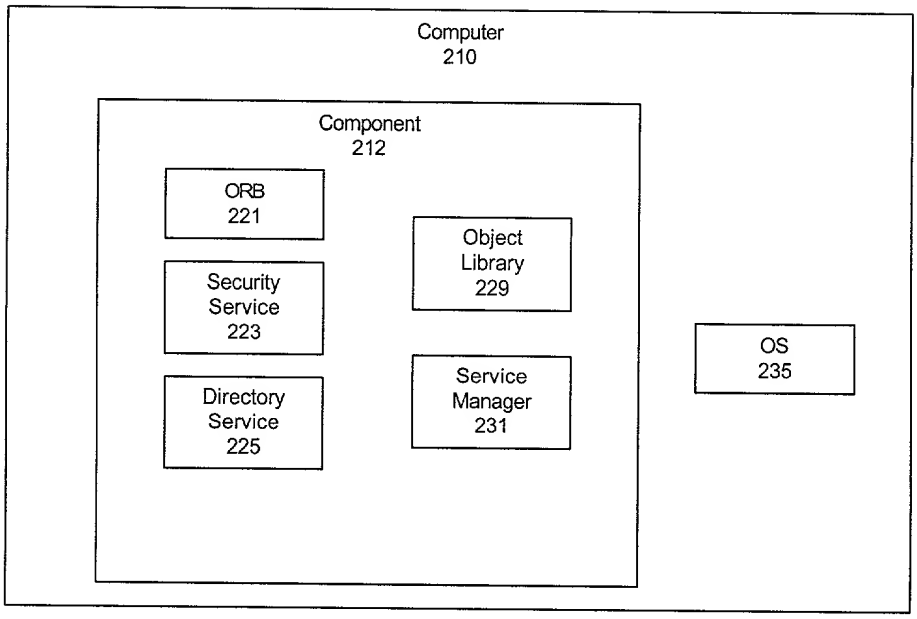

Computer
210
Component
212
ORB
221
Security
Service
223
Directory
Service
225
Object
Library
229
Service
Manager
231
OS
235

Figure 2

09574 P 2478 US

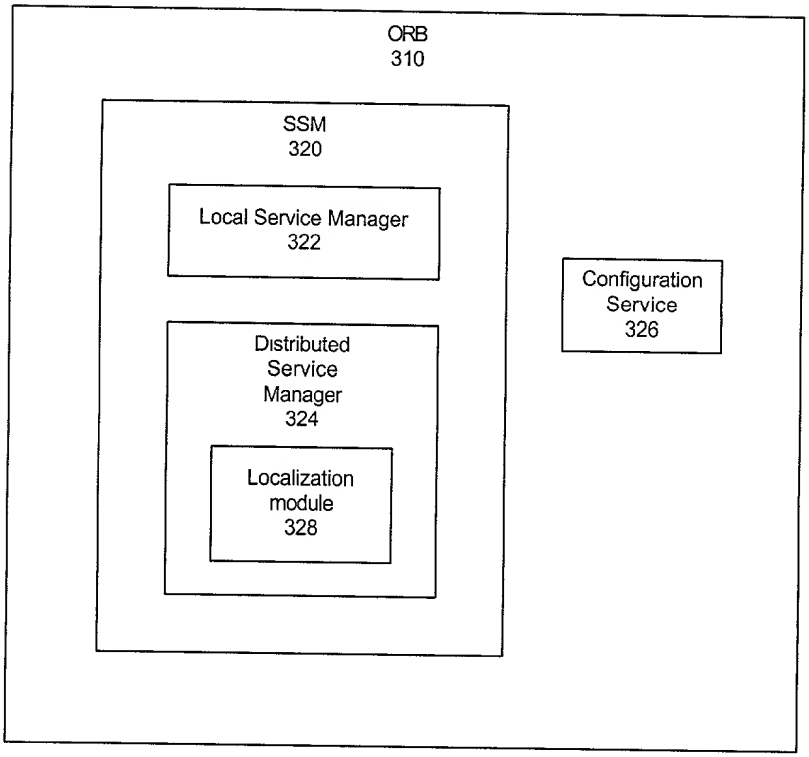


Figure 3

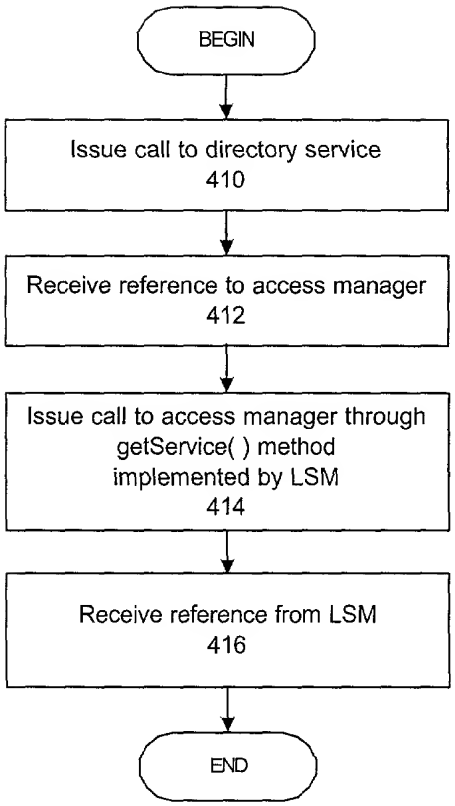

BEGIN
Issue call to directory service
410
Receive reference to access manager
412
Issue call to access manager through
getService( ) method
implemented by LSM
414
Receive reference from LSM
416
END

Figure 4A

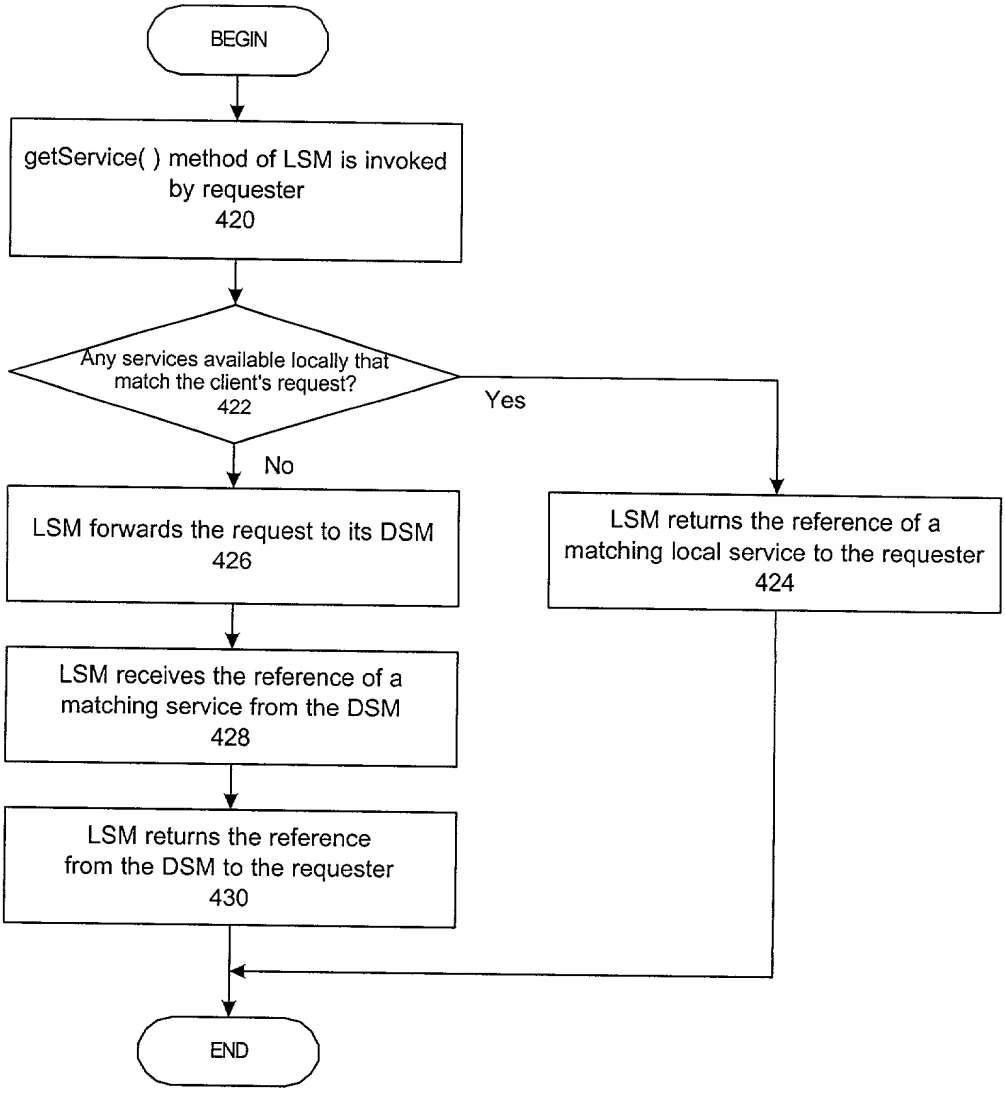

BEGIN
getService( ) method of LSM is invoked by requester
420
Any services available locally that match the client's request?
422
Yes
No
LSM forwards the request to its DSM
426
LSM returns the reference of a matching local service to the requester
424
LSM receives the reference of a matching service from the DSM
428
LSM returns the reference from the DSM to the requester
430
END

Figure 4B

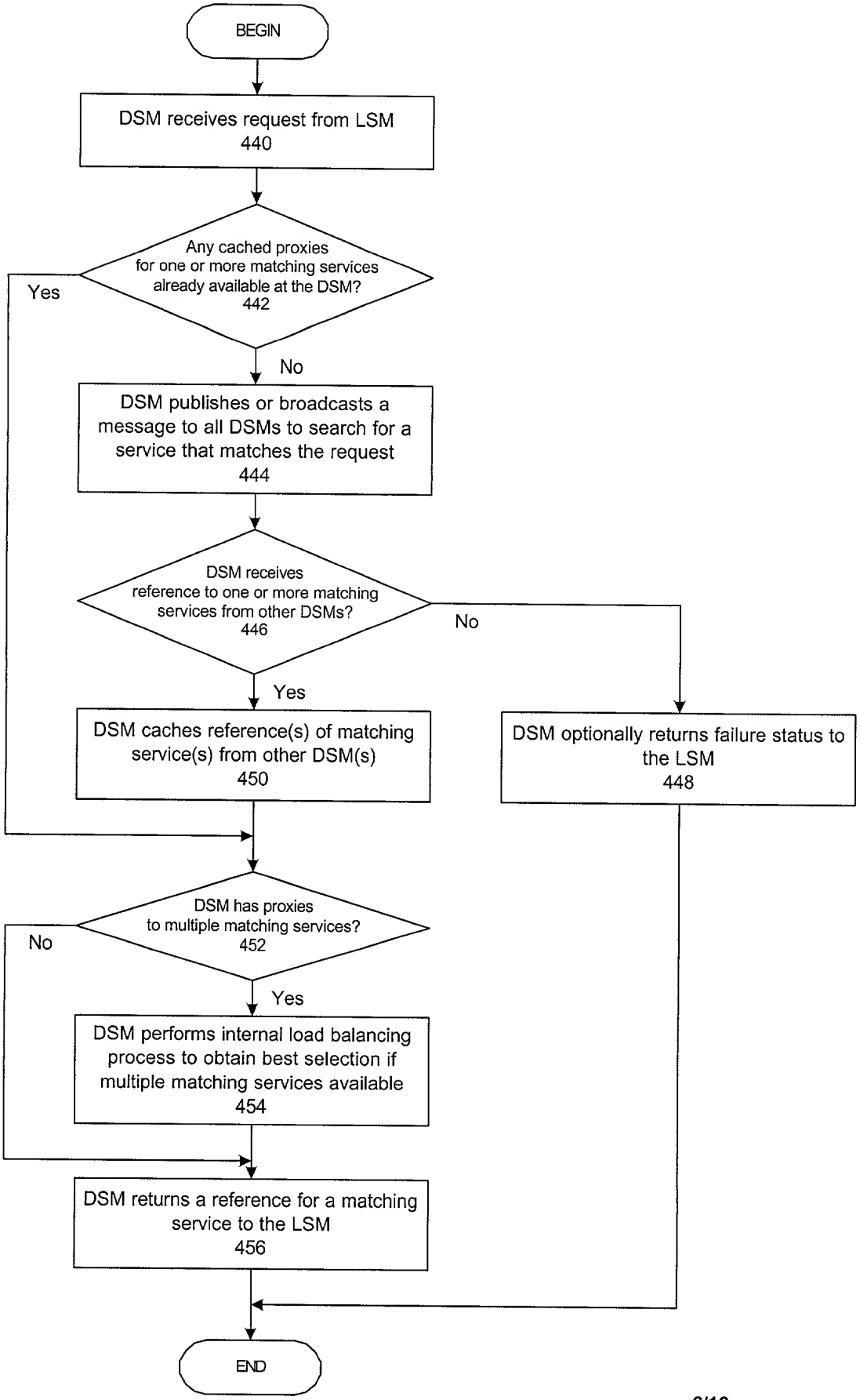

BEGIN
DSM receives request from LSM
440
Any cached proxies for one or more matching services already available at the DSM?
442
Yes
No
DSM publishes or broadcasts a message to all DSMs to search for a service that matches the request
444
DSM receives reference to one or more matching services from other DSMs?
446
No
Yes
DSM caches reference(s) of matching service(s) from other DSM(s)
450
DSM optionally returns failure status to the LSM
448
DSM has proxies to multiple matching services?
452
No
Yes
DSM performs internal load balancing process to obtain best selection if multiple matching services available
454
DSM returns a reference for a matching service to the LSM
456
END

Figure 4C

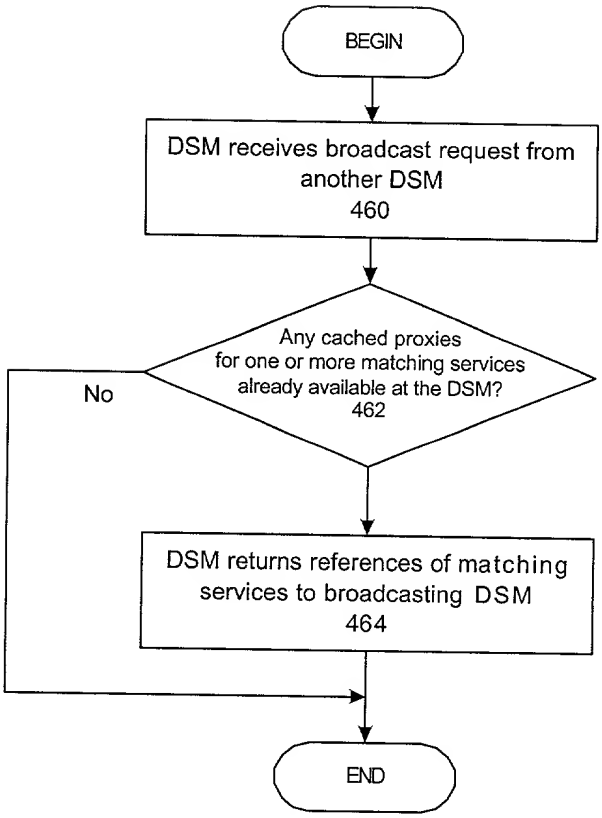

BEGIN
DSM receives broadcast request from another DSM
460
Any cached proxies for one or more matching services already available at the DSM?
462
No
DSM returns references of matching services to broadcasting DSM
464
END

Figure 4D

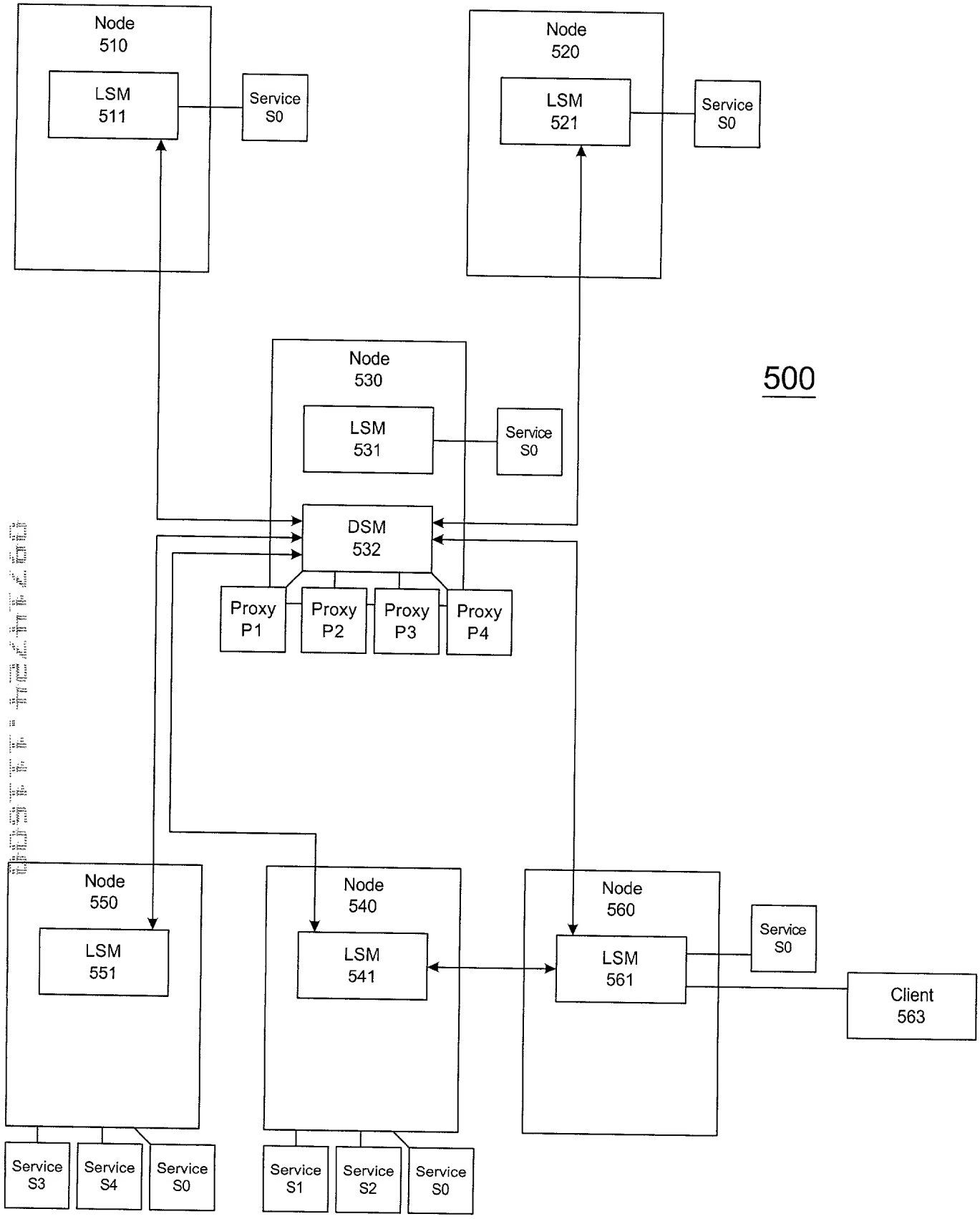

Node
510
LSM
511
Service
S0
Node
520
LSM
521
Service
S0
Node
530
LSM
531
Service
S0
500
DSM
532
Proxy
P1
Proxy
P2
Proxy
P3
Proxy
P4
Node
550
LSM
551
Node
540
LSM
541
Node
560
LSM
561
Service
S0
Client
563
Service
S3
Service
S4
Service
S0
Service
S1
Service
S2
Service
S0

Figure 5

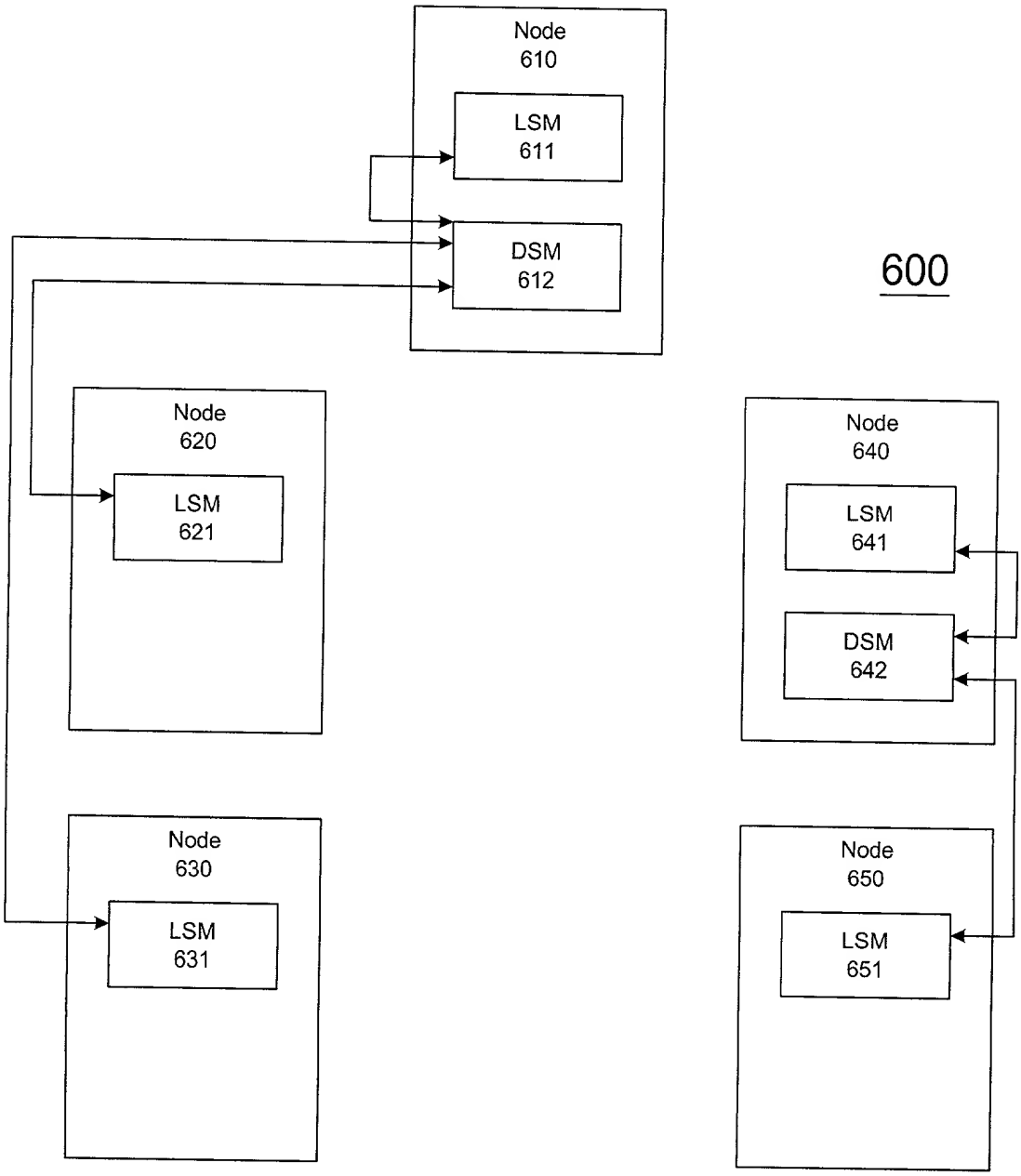
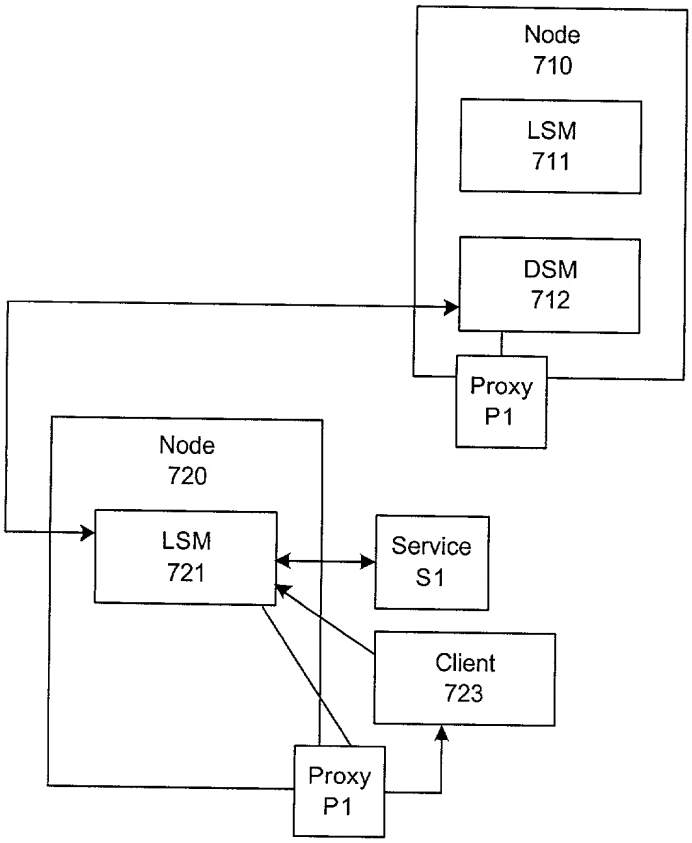

Node
610
LSM
611
DSM
612
600
Node
620
LSM
621
Node
640
LSM
641
DSM
642
Node
630
LSM
631
Node
650
LSM
651

Figure 6


Node
710
LSM
711
DSM
712
Proxy
P1
Node
720
LSM
721
Service
S1
Client
723
Proxy
P1

700

Figure 7

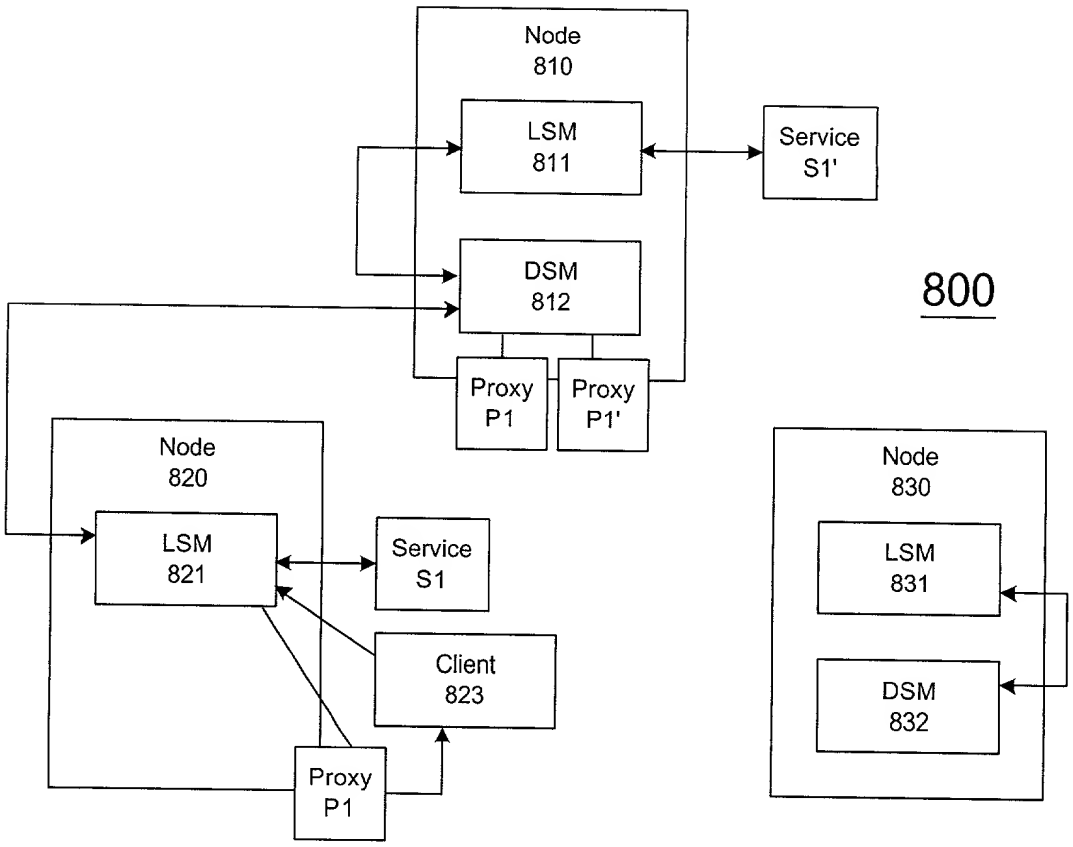

Node
810
LSM
811
Service
S1'
DSM
812
800
Proxy
P1
Proxy
P1'
Node
820
LSM
821
Service
S1
Client
823
Proxy
P1
Node
830
LSM
831
DSM
832

Figure 8

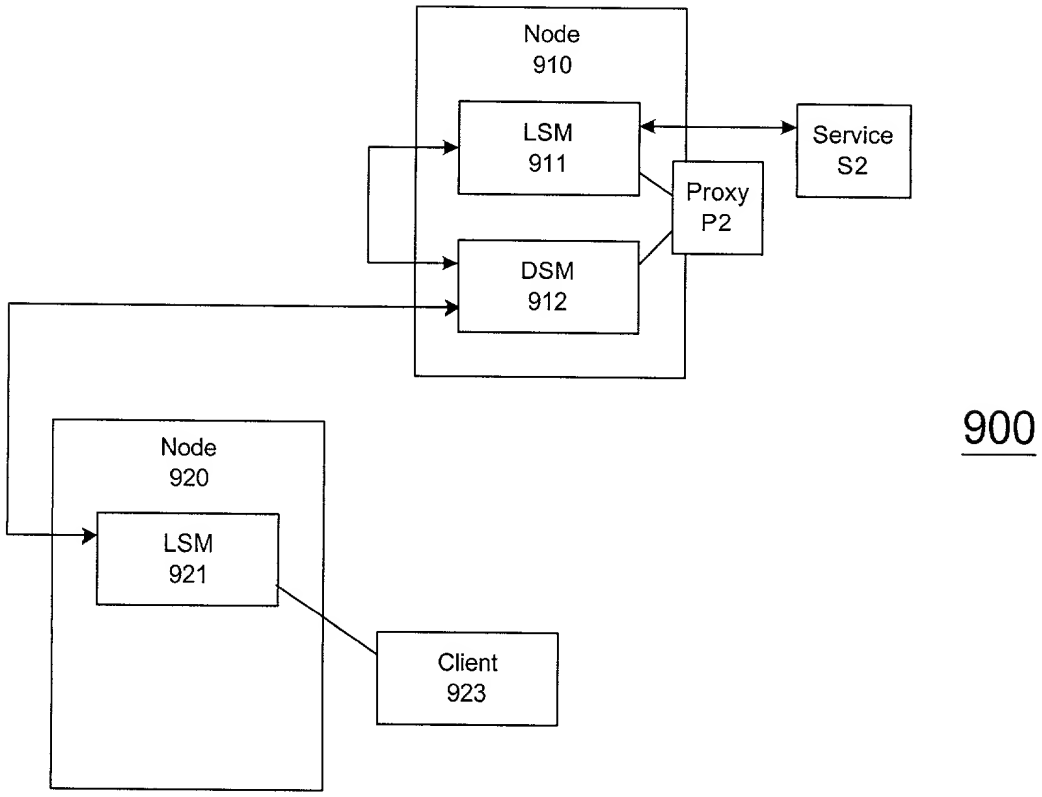


Figure 9A

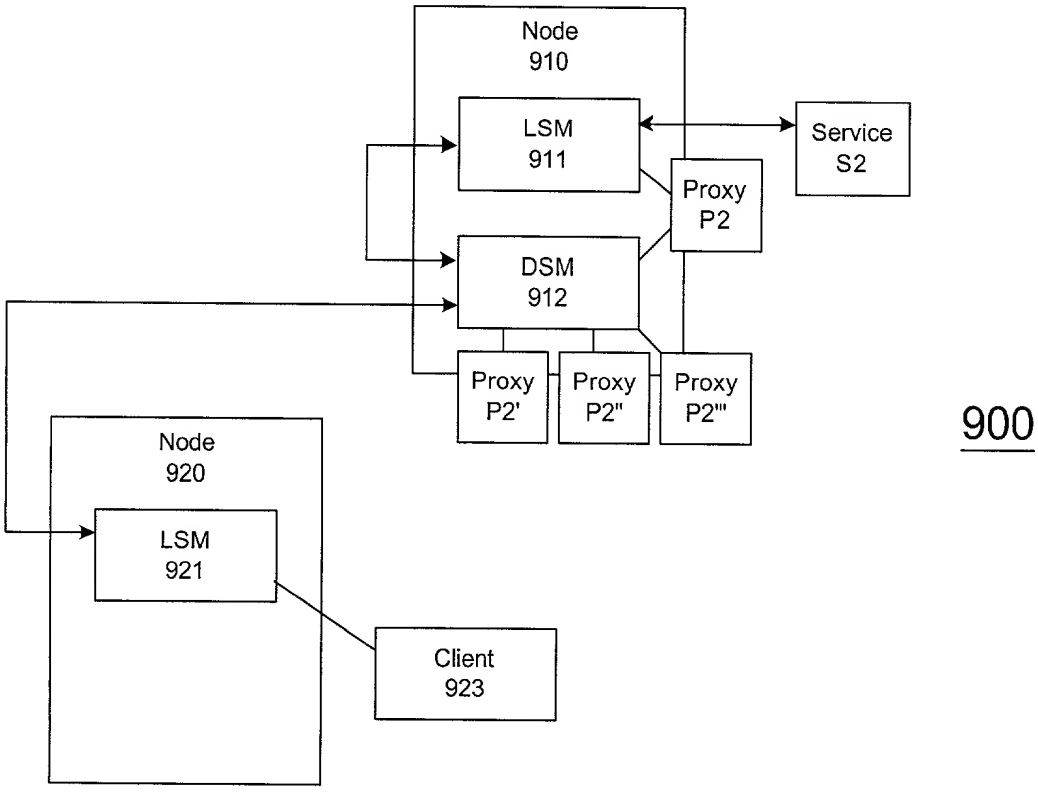


Figure 9A

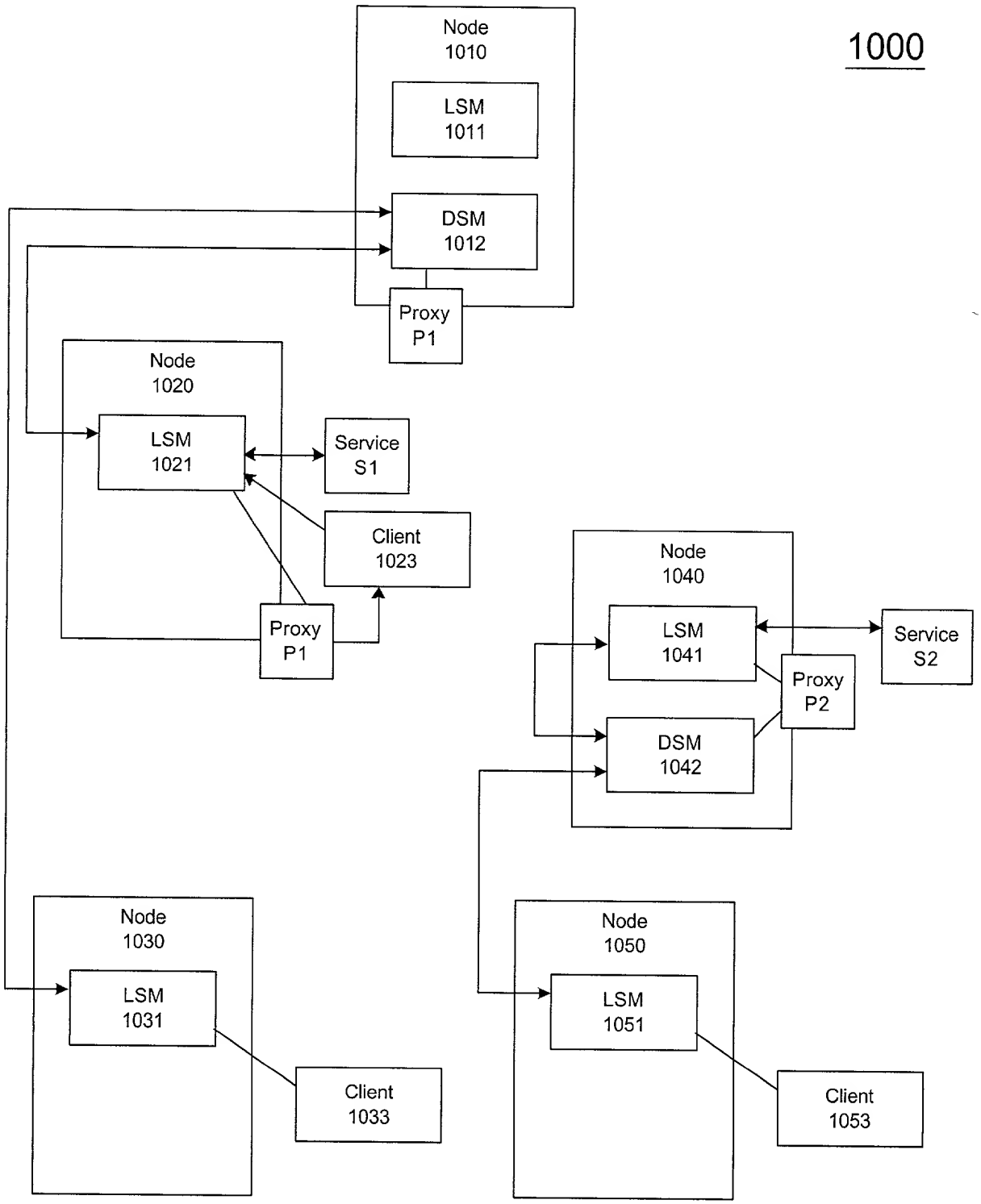

1000
Node
1010
LSM
1011
DSM
1012
Proxy
P1
Node
1020
LSM
1021
Service
S1
Client
1023
Proxy
P1
Node
1040
LSM
1041
Service
S2
Proxy
P2
DSM
1042
Node
1030
LSM
1031
Client
1033
Node
1050
LSM
1051
Client
1053

Figure 10A

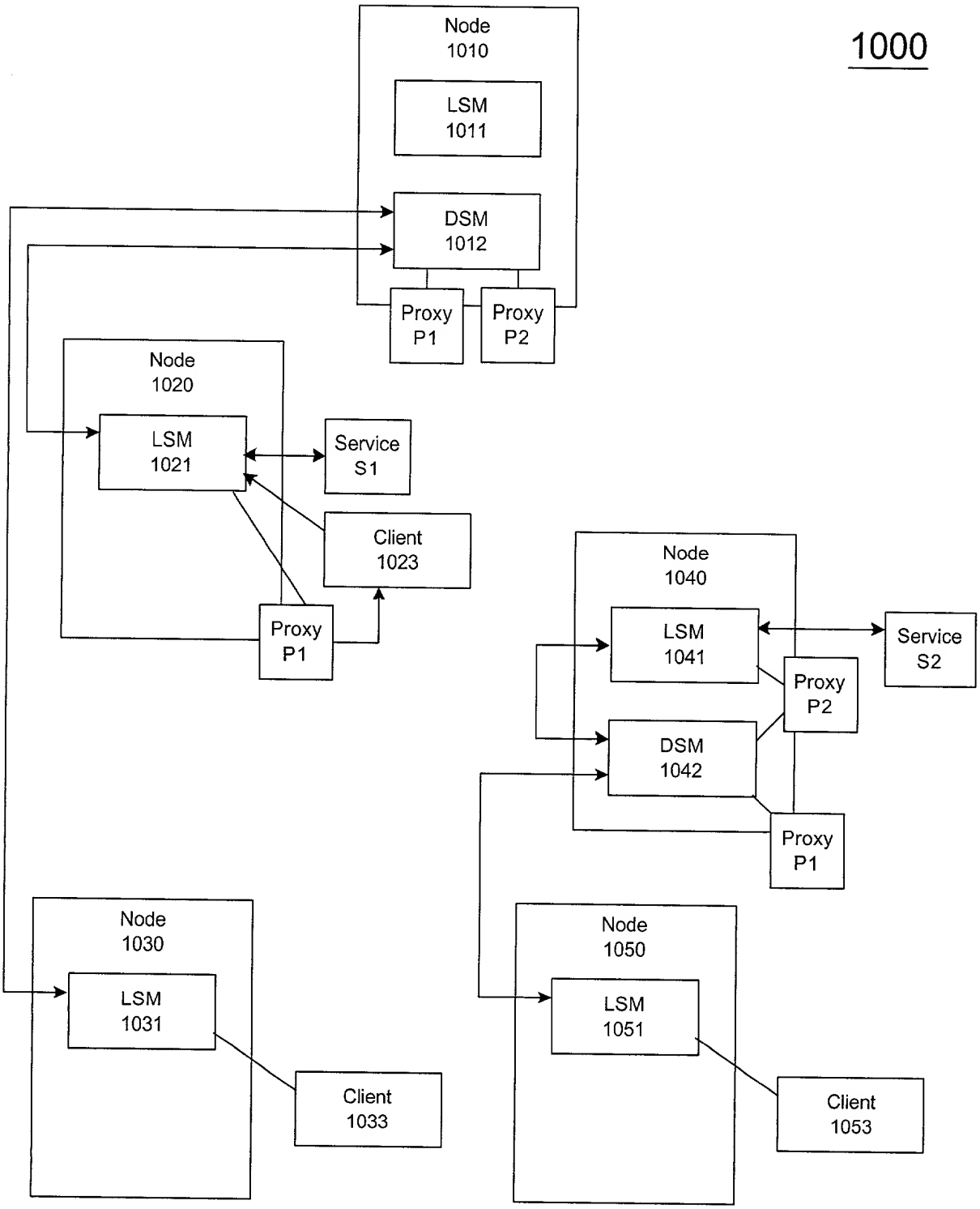

1000
Node
1010
LSM
1011
DSM
1012
Proxy
P1
Proxy
P2
Node
1020
LSM
1021
Service
S1
Client
1023
Proxy
P1
Node
1040
LSM
1041
Service
S2
Proxy
P2
DSM
1042
Proxy
P1
Node
1030
LSM
1031
Client
1033
Node
1050
LSM
1051
Client
1053

Figure 10B

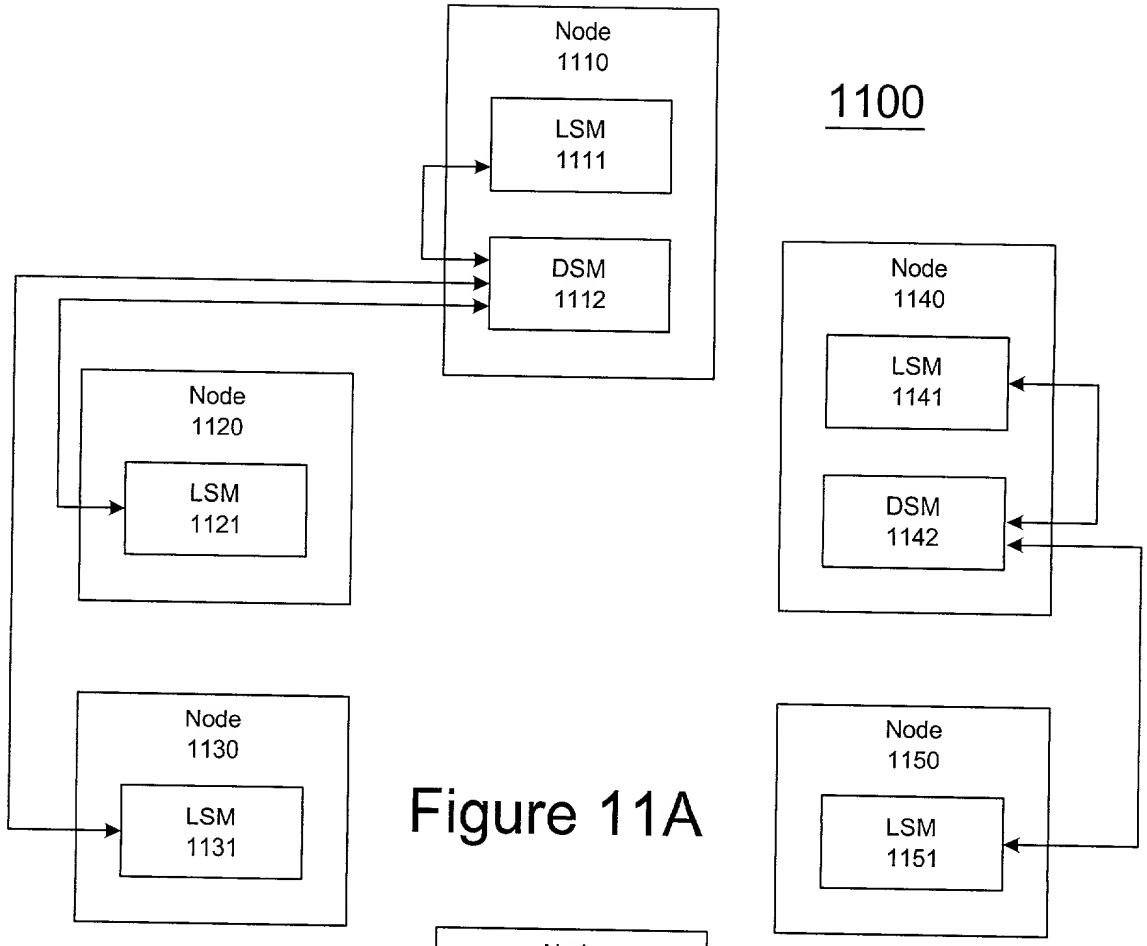


Figure 11A

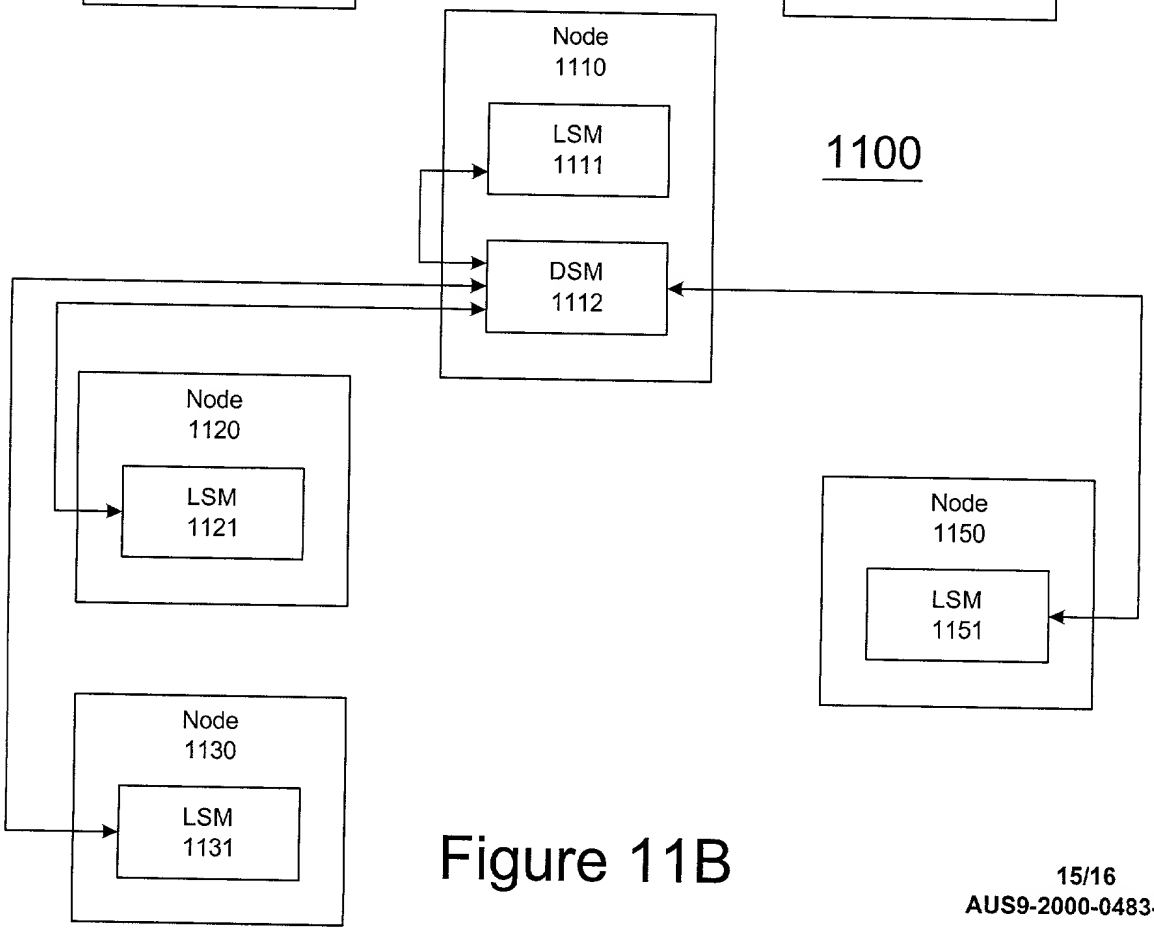


Figure 11B

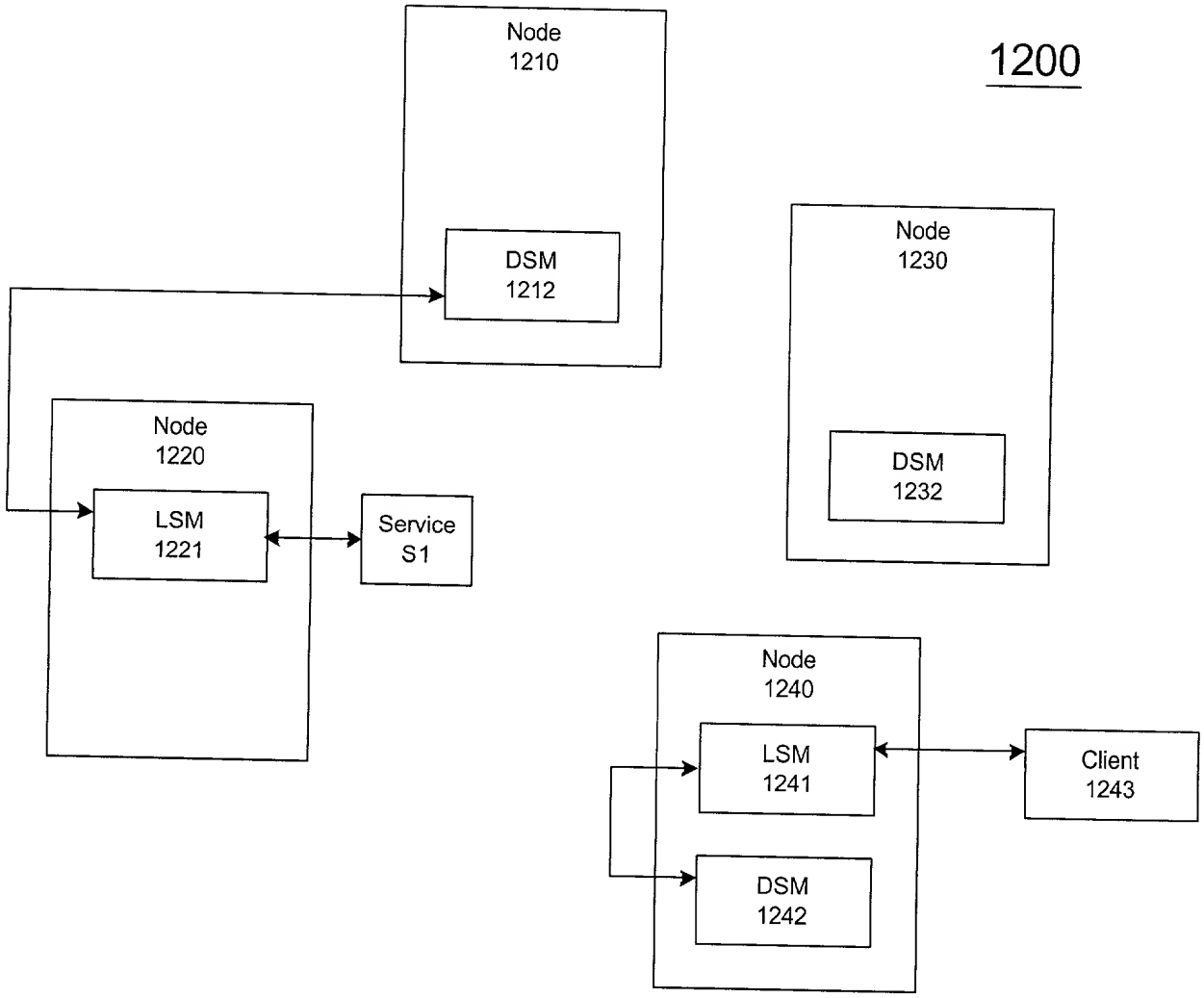

1200
Node
1210
DSM
1212
Node
1230
DSM
1232
Node
1220
LSM
1221
Service
S1
Node
1240
LSM
1241
Client
1243
DSM
1242

Figure 12

DOCKET NUMBER: AUS9-2000-0483-US1

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name;

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

METHOD AND SYSTEM FOR AUTOMATIC LOAD BALANCING OF ADVERTISED SERVICES BY SERVICE INFORMATION PROPAGATION BASED ON USER ON-DEMAND REQUESTS

the specification of which (check one)

X is attached hereto.

___ was filed on _____
as Application Serial No. _____
and was amended on _____
(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s):			Priority Claimed
_____ (Number)	_____ (Country)	_____ (Day/Month/Year)	___ Yes ___ No

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United

States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose information material to the patentability of this application as defined in Title 37, Code of Federal Regulations, §1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial #)	(Filing Date)	(Status)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorneys and/or agents to prosecute this application and transact all business in the Patent and Trademark Office connected therewith:

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DOCKET NUMBER: AUS9-2000-0483-US1

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INVENTOR SIGNATURE: Christopher Michael Morrissey DATE: 11/14/00

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